

Resurvey of Northern Abalone, *Haliotis kamtschatkana*, Populations Along the Central Coast of British Columbia, May 2006

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RESURVEY OF NORTHERN ABALONE, *Haliotis kamtschatkana*, POPULATIONS
ALONG THE CENTRAL COAST OF BRITISH COLUMBIA, MAY 2006

by

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ABSTRACT

Hankewich, S., and Lessard, J. 2008. Resurvey of northern abalone, *Haliotis kamtschatkana*, populations along the central coast of British Columbia, May 2006. Can. Manuscr. Rep. Fish. Aquat. Sci. 2838: vi + 41 p.

The legal harvest of northern abalone has been closed to all parties since 1990 due to conservation concerns. To monitor the status of abalone populations the Department of Fisheries and Oceans Canada has conducted periodic surveys of index sites along the coast of British Columbia (BC) since 1978. The index sites along the central coast of BC were resurveyed in 2006. Four hundred and thirty three abalone were measured at 52 (76.5%) of the 68 index sites surveyed in 2006. The mean shell length (SL) of abalone on the central coast in 2006 was 69.4 mm, significantly smaller than the previous mean SL in the 2001 survey (77.6 mm). The overall density was 0.40 ± 0.06 (SE) abalone/m², a slight increase over the 2001 estimate of 0.27 ± 0.04 abalone/m². Immature (<70 mm SL) and mature (≥ 70 mm SL) abalone densities also slightly increased when compared to those estimated in 2001. Conversely, the density of large adult abalone (≥ 100 mm SL) decreased by 50% between 2001 and 2006, to the current estimate of 0.02 ± 0.01 abalone/m². Large abalone were found at only 17.6% of the sites surveyed. Despite slightly higher density estimates in 2006, there is no statistical evidence of abalone populations rebuilding in the central coast of BC since the fishery closure.

RÉSUMÉ

Hankewich, S., and Lessard, J. 2008. Resurvey of northern abalone, *Haliotis kamtschatkana*, populations along the central coast of British Columbia, May 2006. Can. Manuscr. Rep. Fish. Aquat. Sci. 2838: vi + 41 p.

La pêche de l'orveau nordique, *Haliotis kamtschatkana*, en Colombie-Britannique (CB) est complètement fermée depuis 1990 afin de protéger la conservation de l'espèce. Des relevés à des sites indicateurs ont été effectués par Pêches et Océans Canada depuis 1978 pour surveiller l'état des populations d'orveaux. En mai 2006, 433 orveaux ont été mesurés à 52 (76.5%) des 68 sites échantillonnés sur la côte central de la CB. La longueur moyenne en 2006 était 69.4 mm, une diminution significative comparativement à la longueur moyenne estimée en 2001 de 77.6 mm. La densité totale était estimée à 0.40 ± 0.06 (ES) orveau/m², une faible augmentation comparée à la valeur de 2001 (0.27 ± 0.04 orveau/m²). Les densités d'orveaux immature (<70 mm de longueur) et mature (≥ 70 mm de longueur) ont aussi légèrement augmentées depuis 2001. Par contre, la densité des orveaux de grande taille (≥ 100 mm de longueur) a diminué de 50% entre 2001 et 2006, l'estimé de cette densité en 2006 était 0.02 ± 0.01 (ES) orveau/m². Les orveaux de grande taille étaient présents à 17.6% des sites échantillonnés. Malgré de faibles hausses pour certaines densités, les résultats indiquent que les populations d'orveaux nordiques ne se rétablissent pas sur la côte centrale de la CB depuis la fermeture de la pêche.

INTRODUCTION

Generally occurring in patchy distributions on exposed or semi-exposed coastlines in British Columbia (BC), the northern abalone, *Haliotis kamtschatkana* Jonas, 1845 (henceforth referred to simply as 'abalone'), is found from Alaska to Baja, California (McLean 1966). Until 1990, abalone were harvested by First Nations as a traditional food source, and were a target of recreational divers and a commercial fishery in BC (Campbell 2000). The biology and fishery of the northern abalone were reviewed by Sloan and Breen (1988) and Farlinger and Campbell (1992).

Surveys of abalone at index sites in the north central coast of BC (CC) (Pacific Fishery Management Area (PMFA) 5 and 6) and southeast Haida Gwaii (Queen Charlotte Islands (QCI)) (PFMA 2 east) have been conducted using a standard survey design since 1978 (Breen and Adkins 1979). Much of the commercial fishery for abalone occurred in these areas during 1977-1990 (Harbo 1997). Between 1978 and 1990, abalone abundance declined by 75-80% at surveyed sites in the CC and QCI (Thomas et al. 1990; Farlinger et al. 1991; Campbell 2000). Due to these substantial decreases and subsequent conservation concerns, the Department of Fisheries & Oceans Canada (DFO) placed a moratorium on the harvest of abalone in December of 1990. Despite the harvest closure, their numbers remained low and in 1999, abalone was listed as 'threatened' by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Campbell 2000; Jamieson 2001). In June 2003, abalone was legally listed and protected as threatened under the Species at Risk Act (SARA) (Fisheries and Oceans Canada 2007).

As a consequence of the COSEWIC listing, a National Recovery Strategy for the Northern Abalone was prepared by DFO and the Abalone Recovery Team (Abalone Recovery Team 2002). The short-term measurable objectives set out in the 2002 recovery strategy were "[to] ensure that mean densities of adult (≥ 100 mm shell length (SL)) northern abalone do not decline below $0.1/\text{m}^2$ at surveyed index sites in Haida Gwaii and North and Central Coast, and that the percentage of surveyed index sites without adult (≥ 100 mm SL) northern abalone does not increase to greater than 60%." In September of 2007, the goals of the recovery strategy (Fisheries and Oceans Canada 2007; Lessard et al. 2007b), relevant to the central coast (objective #2 excluded) were expanded and revised to:

- 1) Observe that mean densities of large adult (> 100 mm SL) northern abalone do not decline below 0.1 per m^2 at surveyed index sites in Haida Gwaii and North and Central Coast, and that the percentage of surveyed index sites with large adult (> 100 mm SL) northern abalone does not decrease below 40%.
- 3) Observe at the index sites (in areas without sea otters) that the annual estimated mortality rate for northern abalone is reduced to < 0.20 and the mean densities of mature (≥ 70 mm SL) northern abalone are increased to ≥ 0.32 per m^2 .

- 4) Observe at the index sites (in areas without sea otters) that the proportion of quadrats (m^2) with northern abalone is increased to $> 40\%$.

In order to monitor and evaluate recovery efforts, the surveys of index sites have continued. This paper presents the results of a survey of abalone conducted along the central coast of BC during May 2006 and compares abalone density estimates with those measured in previous index site surveys along the central coast.

METHODS

SURVEY METHODS

Nine central coast (CC) abalone surveys have been completed since 1978 (Breen and Stephanson 1979; Breen and Adkins 1980, 1981, 1982; Breen et al. 1982; Boutillier et al. 1984; Farlinger and Bates 1986; Farlinger et al. 1991; Thomas and Campbell 1996; Campbell et al. 1998; Lessard et al. 2007a). In the early years (1978-1983), the surveyed sites were selected because they supported strong abalone populations which were deemed harvestable. In 1983, an effort was made to resurvey some of these sites which, when conditions permitted, were subsequently sampled each time a survey was completed on the north and central coast. The repeatedly surveyed sites are referred to as 'index sites'. 'All sites' refers to both index sites and additional sites (sites not repeated in subsequent surveys). In 1997, the central coast abalone survey was expanded and many additional sites were randomly selected (Campbell et al. 1998). Of these 1997 additional sites, only the sites repeated in 2001 and 2006 were included. In 2006, a total of 13 sites from 1978, 1980 and 1983, which had not previously been repeated, were resurveyed to increase the number of index sites in some of the general survey areas (see below) (Appendix 6). While a serial spatial analysis was not carried out in this report, it is hoped that by increasing the sample size within each area, spatial analysis will be possible in the future.

Index sites were not evenly distributed along the coast, but were grouped into nine general survey areas to simplify sampling logistics: North Banks Island, Oswald Bay, Pemberton Bay, Lotbinière Bay, Aristazabal Island split into North Aristazabal Is and South Aristazabal Is, Stryker Island, Simonds Group and Spider Island (Fig. 1).

The 2006 CC survey was conducted during 10 days of diving in May, by divers from DFO, and the Kitasoo and Heiltsuk First Nations. The Coast Guard research vessel CCGS *Vector* acted as a live-aboard platform.

For this survey, as in the past, sites were surveyed using the method described by Breen and Adkins (1979). The previously surveyed sites were located using chart records, written site descriptions, photographs and GPS positions. Once each site was located, divers placed a $1m^2$ quadrat at the top of the abalone habitat zone and then sampled 16 quadrats within a 7m by 16m area. The 16 quadrats were arranged in four transects, each 4m apart; and each of the four quadrats within a transect, were 1m apart (i.e. every 2nd quadrat per transect). For each quadrat, divers recorded the algae percent cover and dominant species, the number of sea urchins (all species, but mostly the red sea urchin, *Strongylocentrotus franciscanus*), and any predators. After recording

the habitat data, divers cleared the quadrat of all kelp, urchins and sea stars to ensure all exposed abalone were easily detectable. Divers then recorded the depth and substrate type, and measured, with callipers, the shell length (SL) in mm of each exposed abalone. In previous years, if no abalone were encountered in the first eight quadrats, the dive was aborted and the site count was scored as zero. Following the recommendation of the QCI 2002 survey report (Atkins et al. 2004), all 16 quadrats were sampled at all sites, even if no abalone were observed in and around the first eight.

ANALYTICAL METHODS

The addition of new index sites in 2006, and updates and revisions to previous data resulted in some changes to previous years' size frequency and density values. Therefore, estimates presented in this paper may differ slightly from previously published values.

A Kolmogorov-Smirnov two-sample test was used to test for differences in mean SL between each of the nine general survey areas in 2006. Mean SL was compared across all survey years using one-way ANOVA. If differences were detected at the 0.05 confidence level, a post-hoc Bonferroni test was used for comparisons between years (SYSTAT 2000).

Densities were calculated for each site as the number of abalone/m² for several size categories: 'all sizes' (total), immature (<70 mm SL), mature (≥70 mm SL) and large (≥100mm SL) which was previously referred to as 'legal'. Seventy millimetres was selected as the size of maturity because it is the smallest size at which 100% of abalone are mature (Campbell et al. 1992). In previous years, densities were also calculated for pre-recruit (92-99 mm SL) and new-recruit (100-106 mm SL) size classes. These densities referred to abundances of abalone just prior to entering the fishery and newly fishery-recruited abalone. However, as the abalone fishery has been closed for >16 years and these size categories are now comprised of so few individuals that they have become meaningless, the 'pre-recruit' and 'new recruit' densities were not calculated in this report.

Occasionally, the number of abalone measured did not match the number counted during the dive because some abalone were inaccessible or their shells were broken. For this reason, the size frequencies for each site were used to estimate the proportion of abalone within each size category. Densities for each size category (d_i) were calculated as:

$$d_i = \frac{n_i}{n} \times d \quad (1)$$

where n_i is the number of abalone measured in category i , n is the total number of abalone measured in the sample and d is the density (abalone/m²) calculated from the total abalone count from the 16 quadrats.

Similar to the 2001 survey, in an attempt to reduce the time spent at each site, divers did not turn over boulders and rocks to search for cryptic abalone. Searching for cryptic individuals is time consuming, and the majority (>90%) of fully mature abalone

(≥ 70 mm SL) are exposed (Cripps and Campbell 1998). Consequently, counting only exposed abalone allowed more sites to be included in the survey. Data for cryptic abalone, gathered from years where counts were kept separate (1989 and 1993), were excluded from the analyses in this paper. For the years in which cryptic abalone were counted but the counts were not separated from the exposed counts (1979, '80, '83, and '85), a correction factor was used to account for the number of cryptic abalone from each site based on the frequency of cryptic abalone in 1989 and 1993. The cryptic correction factors as calculated in the 2001 CC survey report were 0.836 for immature (< 70 mm SL) and 0.991 for mature (≥ 70 mm SL) and large abalone (≥ 100 mm SL) (Lessard et al. 2007a). Exposed densities for 'all sizes', for survey years in which cryptic and exposed abalone counts were not separated (1979, '80, '83, and '85), were calculated as the sum of immature and mature densities.

The non-parametric Kruskal-Wallis test (SYSTAT 2000) was used to compare densities between areas in 2006, as well as between all years for each size category ('all sizes', immature, mature and large adult abalone). If differences were detected at the 0.05 confidence level, a Mann-Whitney U was used for comparisons between years. All differences were considered statistically different at the $P < 0.05$ confidence level.

Mortality rate for 'all sizes' abalone was estimated using the 2001 and 2006 survey data and established growth models based on the method described in Zhang et al. (2007). The 2001 size frequency distribution and density estimate (including cryptic proportion calculated from established relationship) were used to predict the density of abalone in 2006. The mortality rate was estimated by comparing the predicted density with the 2006 observed density estimate.

RESULTS

SURVEY SUMMARY

A total of 68 index sites were sampled for abalone densities during 10 days of diving in May, 2006. An average of 39.3 minutes (minimum 23, maximum 71) was spent sampling each site (Appendix 1). In general, the sites were composed of bedrock and/or boulder/cobble substrate, and many sites also contained some sand or shell. The dominant kelp species consisted of *Nereocystis luetkeana*, *Macrocystis integrifolia*, and *Laminaria* spp, with *Desmarestia* spp. also present at many sites. Encrusting coralline algae was present at all sites (Appendix 2). Site densities of sea urchins ranged between 0-25.2 /m², with a mean of 6.0 ± 0.8 /m².

SIZE FREQUENCY

Four hundred and thirty three abalone were measured during the CC survey in 2006. Mean SL for each site are presented in Appendix 3. Overall, the mean SL was $69.4 \text{ mm} \pm 1.1 \text{ mm}$: the smallest abalone measured was 2 mm (at Stryker Island), and the largest was 122 mm, found in Oswald Bay (Fig. 2, 3; Tables 1, 2). In general, a trend towards decreasing abalone shell length from north to south existed, though the mean SL at the Simonds Group and Spider Island were larger than at South Aristazabal Is. The mean SL at North Banks Island (83.0 mm) and Oswald Bay (80.4 mm) were significantly larger than all other areas except each other. Stryker Island abalone had a

significantly smaller mean SL (56.9mm) than all areas except North and South Aristazabal Is and Spider Island (Tables 1, 2).

While the range of measurements was large in all years (Fig. 3; Table 3), the overall mean SL of abalone in the 2006 survey (69.4 mm) decreased significantly from the mean SL in 2001 (77.6 mm) (Tables 3, 4), and was significantly smaller than all other years, except 1980. The largest mean SL was observed in 1978, significantly different from all other survey years.

DENSITY

Density estimates by size categories for all sites surveyed in 2006 are presented in Appendix 3. For each 'index site', total density estimates and the number of quadrat sampled across all survey years are presented in Appendix 4; while mature and large density estimates are in Appendix 5. Density and mean SL estimates for additional (non-repeated) sites surveyed during 1978-85 are presented in Appendix 7.

Total abalone density in 2006 was 0.40 ± 0.06 abalone/m². 'All sizes' densities by area ranged from a minimum of 0.23 abalone/m² at South Aristazabal Is and Stryker Island to a maximum of 0.89 abalone/m² at Pemberton Bay (Table 5).

Mean density estimates for immature, mature and large abalone across the CC were 0.18 abalone/m², 0.23 abalone/m², and 0.02 abalone/m², respectively (Table 5). Pemberton Bay had the highest immature and mature abalone densities (0.31 abalone/m² and 0.58 abalone/m²). Oswald Bay had the lowest immature density at 0.07 abalone/m², and the lowest mature density was found at Stryker Island (0.06 abalone/m²). North Banks Island and Oswald Bay had the highest densities of large abalone (0.07 abalone/m² and 0.05 abalone/m², respectively). All other areas had large abalone densities between 0.01 abalone/m² and 0.03 abalone/m², with the exception of Lotbinière Bay, where no large abalone were measured in the area.

Abalone densities continually declined between 1980 and 2001 (Fig. 4; Table 6). In 2006, there was a slight increase in the 'all sizes' abalone densities, but the difference was non-significant (Table 7). 'All sizes' and immature abalone densities in 2006 were significantly lower than survey years prior to 1989, but not after. The density in the mature size category was also slightly higher (non-significant) than those found in 2001, but significantly lower than all years previous to 1997. Large adult abalone density has decreased by half since 2001, though non-significantly, and is significantly lower than all other survey years.

PERCENT OF SITES WITH ABALONE

Abalone were found in all survey areas on the central coast in 2006 (Table 8). Overall, the percentage of sites with abalone of any size was 76.5% (52/68 sites surveyed), a slight increase from 72.7% in 2001 (Fig. 5). However, this increase may be an artefact of the change in protocol to sampling all 16 quadrats at each site. At eight of the sites sampled, abalone were found only after the first 8 quadrats (Fig. 6). Consequently, if the site survey had not continued beyond the first 8 quadrats, 15.4% of the sites where abalone were found in the current survey would have been scored as zero. While the first abalone found at a site is most often in the first 3 quadrats (Fig. 6), the overall sum of abalone found across the CC by quadrat number is relatively similar

(Fig. 7), though quadrats number 4, 8, 12, and 14 appear to contain slightly fewer abalone.

The percentage of sites with exposed large abalone continued to decline from 89.3% in 1985, and 29.1% in 2001 to the current estimate of 17.6% (12/68 sites surveyed) (Table 8, Fig. 5).

PROPORTION OF QUADRATS WITH ABALONE

The proportion of abalone (abalone/m²) found in secondary sampling units (quadrats) at survey sites declined severely between 1978 and 1989 (the last active fishery year), and continued to decrease between 1989 and 2007 (Fig. 8). Conversely, the proportion of quadrats with zero abalone increased from 1978 to the present survey in 2006. However, the values in 2006 are slightly more optimistic than those of 2001. Overall, despite the fishery closure in 1990, the likelihood of encountering more than 1 abalone per quadrat has decreased substantially.

MORTALITY RATE

The estimated annual mortality rate of abalone in the CC was 0.33 ± 0.07 SD (standard deviation).

DISCUSSION

The mean size of abalone measured on the central coast in 2006 (69.4 mm SL) was significantly smaller than every other survey year since 1978, with the exception of 1980 (68.2 mm SL). This decrease in mean size was the result of a greater proportion of small individuals combined with a decrease in maximum SL. Overall abalone density increased slightly since 2001 (32.5%). However, this difference was not significant, and was largely due to an increase in immature density. Conversely, abalone in the large size class decreased by 50% between 2001 and 2006.

The disparity in trends between size classes of abalone may be an indication of continued poaching pressure and sea otter predation. Poaching is a size selective activity, and is a serious threat to abalone populations in BC (Lessard et al. 2007a, b). Sea otters currently occupy the central part of the central coast, from the Goose Group to Cape Mark (Nichol et al. 2005). While sea otters forage in and around the Simonds group and also possibly Spider Island, no rafts have yet been observed in these areas (Nichol et al. 2005; J. Lessard, DFO, Nanaimo, pers. comm.).

As an important predator of marine invertebrates including abalone (Watson 2000), sea otters are expected to have significant effects on, particularly large, abalone populations in the areas they occupy (Cripps and Campbell 1998; Lessard et al. 2007a, b). Although divers in the area have seen evidence of sea otter predation on geoducks and abalone (S. Hankewich and J. Lessard, DFO, Nanaimo, pers. comm.) it is not yet clear to what extent sea otters are affecting abalone populations in the CC. The smallest abalone mean size observed in the 2006 CC survey was at Stryker Island, where sea otters have been established since 1996 and rafts have been regularly encountered (Nichol et al. 2005). In addition, some sites at Stryker Island and the

Simonds Group underwent drastic decreases in total and large abalone density between 2001 and 2006, while others increased in that time frame.

In spite of continued poaching and predation pressure, the percent of sites with abalone and overall abalone densities in the CC increased in 2006. However, the increased number of sites with abalone may largely due to the change in protocol to sampling all 16 quadrats at each site. Had site abalone counts ended if no abalone were encountered in the first 8 quadrats, then 15% of the sites where abalone were found in this survey would have been scored as zero. This is a substantial number, indicating that accurate density estimates will necessitate sampling all 16 quadrats at each site. For this reason, we recommend that future surveys continue to follow this protocol.

Upon examination of the numbers of abalone found by quadrat number further influences of sampling protocol are seen. The first abalone seen at a site is most often found in the first quadrat, which may be an indicator of diver bias in the placement of the first quadrat. Furthermore, the structure of the Breen method is such that quadrats 1, 4, 8, 12, and 16 fall near the edges of the zone where abalone are most frequently found. This appears to be reflected in the abalone counts, as quadrat numbers 4, 8, 12, and 16 contained slightly fewer abalone in this survey. Fortunately, these biases are not likely to affect population estimates greatly for a few reasons: population estimates are calculated by site rather than by quadrat, the sum of abalone found by quadrat number is relatively similar despite small differences and, most importantly, the sampling protocol is relatively unchanged since 1978, thus estimates are comparable between years. Nevertheless, it is important to note these biases, particularly if comparisons are to be made to estimates generated using alternate survey methods.

At first glance, the percentage changes in abalone densities by size category between 2001 and 2006 appear to be large, and we would expect to see statistical significance between the two surveys: the overall abalone density has risen 48% since 2001, the densities of immature and mature abalone have increased by 80% and 35%, respectively, and the density of large abalone decreased by 50%. However, none of these differences were statistically significant. Abalone densities were at such relatively low levels that even large relative changes in densities correspond to very small numerical differences. For example, the 48% increase in overall density was actually only a 0.13 abalone/m² increase- the approximate equivalent of measuring one extra abalone in every 7 quadrats. As the densities decrease, this becomes even more evident. The 50% decrease in large abalone densities is due to a decrease of 0.02 abalone/m². This is the equivalent of 1 less abalone in every 50 quadrats- a number which could most certainly be due strictly to chance. Thus, in order to observe genuine evidence of recovery, the relative changes in abalone density will have to be very large. Furthermore, if abalone densities continue to decline, these changes will need to be proportionately larger to find significant differences in densities between surveys.

CONCLUSION

There has been no statistical evidence of abalone populations rebuilding in the central coast of BC in the 16 years since abalone were protected by harvest closures.

Despite slight density increases in 2006, the objectives set in the National Abalone Recovery Strategy have not yet been met. The mean density of large adult abalone (≥ 100 mm shell length) along the central Coast in 2006 was 0.02 abalone/m², considerably below the target of 0.1/m². The percentage of sites with large abalone has decreased to well below recovery strategy's target of not less than 40%: at the time of this survey only 17.6% of sites on the central Coast had large abalone, and no large abalone were found in one area (Lotbinière Bay). Similarly, the proportion of quadrats with abalone in 2006 was 21%, a slight increase from the 2001 value of 17%, but much lower than the goal of >40%. The annual estimated mortality rate for abalone in the CC is 0.33, still well above the goal of <0.20.

In order for abalone in BC to recover, this high mortality must be addressed; the immature abalone present today must be allowed to reach maturity, and the decline of large adult abalone in areas without sea otters must be halted to ensure future recruitment.

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Table 1. Summary of exposed abalone shell length data from surveyed sites in each general survey areas on the central coast, May 2006. SE = standard error of the mean.

Area	Shell Length (mm)					Total Count	Percent Large (>100mm SL)
	Mean	Median	SE	Minimum	Maximum		
North Banks Island	83.0	85	2.6	38	116	52	17.3%
Oswald Bay	80.4	86.5	4.8	28	122	24	20.8%
Pemberton Bay	72.6	76	2.0	36	112	57	1.8%
Lotbinière Bay	72.1	79	3.1	25	98	37	0.0%
North Aristazabal Is	62.8	67	2.9	6	103	69	2.9%
South Aristazabal Is	60.7	59	3.6	28	105	33	3.0%
Stryker Island	56.9	61	4.4	2	104	29	3.4%
Simonds Group	69.9	74	2.2	8	110	95	2.1%
Spider Island	63.6	70	3.8	24	108	37	8.1%
All areas	69.4	74	1.1	2	122	433	5.5%

Table 2. Probability values of Kolmogorov-Smirnov test comparing mean SL of abalone surveyed within index sites on the central coast in 2006. Values in bold indicate significant difference ($P < 0.05$).

General Survey Area	North Banks Island	Oswald Bay	Pemberton Bay	Lotbinière Bay	North Aristazabal Is	South Aristazabal Is	Stryker Island	Simonds Group
Oswald Bay	0.769							
Pemberton Bay	0.002	0.004						
Lotbinière Bay	0.012	0.046	0.433					
North Aristazabal Is	0.001	0.004	0.019	0.064				
South Aristazabal Is	0.000	0.002	0.010	0.008	0.421			
Stryker Island	0.000	0.001	0.001	0.002	0.086	0.945		
Simonds Group	0.008	0.018	0.833	0.772	0.062	0.024	0.001	
Spider Island	0.000	0.002	0.117	0.035	0.846	0.555	0.078	0.255

Table 3. Summary of exposed abalone shell length data from surveyed sites on the central coast by year.

Year	Shell Length (mm)					Total Count	Percent Large (>100mm SL)
	Mean	Median	SE	Minimum	Maximum		
1978	94.9	97	1.0	30	149	454	46.0%
1979	81.6	83	0.7	17	139	804	20.0%
1980	68.2	70	0.7	14	129	959	8.2%
1983	80.9	82	0.6	8	131	1076	15.0%
1985	82.5	85	0.8	6	129	702	21.1%
1989	81.3	82	1.4	20	140	227	18.5%
1993	78.4	80	1.1	16	126	421	17.8%
1997	80.7	84	1.4	20	142	317	23.7%
2001	77.6	81	1.4	29	122	230	15.2%
2006	69.4	74	1.1	2	122	433	5.5%

Table 4. ANOVA results comparing the mean shell length of abalone from 'all sites' between years. Numbers represent p-values from the multiple comparison Bonferroni test. Bold numbers indicate significant difference ($p < 0.05$).

Year	Year								
	1978	1979	1980	1983	1985	1989	1993	1997	2001
1979	0.000								
1980	0.000	0.000							
1983	0.000	1.000	0.000						
1985	0.000	1.000	0.000	1.000					
1989	0.000	1.000	0.000	1.000	1.000				
1993	0.000	0.510	0.000	1.000	0.082	1.000			
1997	0.000	1.000	0.000	1.000	1.000	1.000	1.000		
2001	0.000	0.507	0.000	1.000	0.114	1.000	1.000	1.000	
2006	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 5. Mean exposed abalone density estimates (number/m²) by size category and general survey area, central coast in 2006. Values in brackets are standard errors of the means.

	North Banks Island	Oswald Bay	Pemberton Bay	Lotbinière Bay	North Aristazabal Is	South Aristazabal Is	Stryker Island	Simonds Group	Spider Island	All Sites
No. of Sites	8	6	4	8	10	9	8	8	7	68
All Sizes	0.41 (0.27)	0.25 (0.13)	0.89 (0.20)	0.29 (0.10)	0.43 (0.12)	0.23 (0.07)	0.23 (0.12)	0.74 (0.26)	0.33 (0.12)	0.40 (0.06)
Immature (<70 mm SL)	0.08 (0.05)	0.07 (0.03)	0.31 (0.14)	0.10 (0.03)	0.23 (0.06)	0.15 (0.04)	0.28 (0.14)	0.29 (0.16)	0.16 (0.08)	0.18 (0.03)
Mature (≥ 70 mm SL)	0.33 (0.23)	0.18 (0.12)	0.58 (0.14)	0.19 (0.07)	0.21 (0.07)	0.08 (0.04)	0.06 (0.04)	0.45 (0.14)	0.17 (0.10)	0.23 (0.04)
Large (≥ 100 mm SL)	0.07 (0.07)	0.05 (0.04)	0.02 (0.02)	0.00	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	0.02 (0.01)	0.03 (0.02)	0.02 (0.01)

Table 6. Mean exposed abalone density estimates (number/m²) by year and size category from 'all sites' surveyed on the central coast. Values in brackets are the standard errors of the means.

	Year									
	1978	1979	1980	1983	1985	1989	1993	1997	2001	2006
Number of Sites Sampled	12	14	19	42	28	26	33	47	55	68
All Sizes	2.40 (0.43)	2.94 (0.66)	3.09 (0.49)	1.58 (0.26)	1.50 (0.18)	0.55 (0.11)	0.46 (0.07)	0.42 (0.07)	0.27 (0.04)	0.40 (0.06)
Immature (<70mm SL)	0.27 (0.08)	0.59 (0.13)	1.40 (0.31)	0.37 (0.08)	0.32 (0.07)	0.14 (0.05)	0.15 (0.02)	0.12 (0.03)	0.10 (0.02)	0.18 (0.03)
Mature (≥70mm SL)	2.13 (0.38)	2.35 (0.61)	1.68 (0.30)	1.22 (0.21)	1.18 (0.03)	0.41 (0.08)	0.32 (0.06)	0.30 (0.06)	0.17 (0.03)	0.23 (0.04)
Large (≥100mm SL)	1.10 (0.22)	0.62 (0.17)	0.26 (0.09)	0.24 (0.04)	0.33 (0.07)	0.10 (0.02)	0.08 (0.02)	0.10 (0.02)	0.04 (0.01)	0.02 (0.01)

Table 7. Mann-Whitney U test probabilities comparing mean densities between years by size category from 'all sites' on the central coast. P-values in bold indicate significant difference ($p < 0.05$).

Year	Year								
	1978	1979	1980	1983	1985	1989	1993	1997	2001
All sizes									
1979	0.719								
1980	0.543	0.636							
1983	0.030	0.026	0.003						
1985	0.082	0.035	0.008	0.457					
1989	0.000	0.000	0.000	0.000	0.000				
1993	0.000	0.000	0.000	0.000	0.000	0.957			
1997	0.000	0.000	0.000	0.000	0.000	0.337	0.232		
2001	0.000	0.000	0.000	0.000	0.000	0.006	0.002	0.023	
2006	0.000	0.000	0.000	0.000	0.000	0.101	0.084	0.459	0.172
Immature (< 70mm SL)									
1979	0.072								
1980	0.002	0.109							
1983	0.958	0.031	0.000						
1985	0.848	0.053	0.001	0.728					
1989	0.075	0.000	0.000	0.005	0.002				
1993	0.346	0.001	0.000	0.076	0.051	0.107			
1997	0.036	0.000	0.000	0.001	0.000	0.931	0.056		
2001	0.033	0.000	0.000	0.000	0.000	0.835	0.045	0.882	
2006	0.233	0.000	0.000	0.042	0.018	0.111	0.789	0.058	0.056
Mature (≥ 70mm SL)									
1979	0.719								
1980	0.240	0.362							
1983	0.009	0.018	0.075						
1985	0.018	0.027	0.182	0.577					
1989	0.000	0.000	0.000	0.002	0.000				
1993	0.000	0.000	0.000	0.000	0.000	0.305			
1997	0.000	0.000	0.000	0.000	0.000	0.113	0.353		
2001	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.031	
2006	0.000	0.000	0.000	0.000	0.000	0.007	0.029	0.168	0.446
Large (≥ 100mm SL)									
1979	0.031								
1980	0.000	0.014							
1983	0.000	0.008	0.742						
1985	0.000	0.051	0.415	0.493					
1989	0.000	0.000	0.149	0.034	0.014				
1993	0.000	0.000	0.022	0.003	0.000	0.385			
1997	0.000	0.000	0.011	0.001	0.000	0.182	0.429		
2001	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.052	
2006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.146

Table 8. Percent of sites by general survey area with exposed abalone of any size and exposed large ($\geq 100\text{mm}$ SL) abalone at index sites along the central coast, 2006.

Area	% of sites with abalone		Number of Sites
	Total	Large	
North Banks Island	37.5	12.5	8
Oswald Bay	83.3	33.3	6
Pemberton Bay	100.0	25.0	4
Lotbinière Bay	75.0	0.0	8
North Aristazabal Is	90.0	20.0	10
South Aristazabal Is	88.9	11.1	9
Stryker Island	50.0	12.5	8
Simonds Group	87.5	25.0	8
Spider Island	85.7	28.6	7
Total	76.5	17.6	68

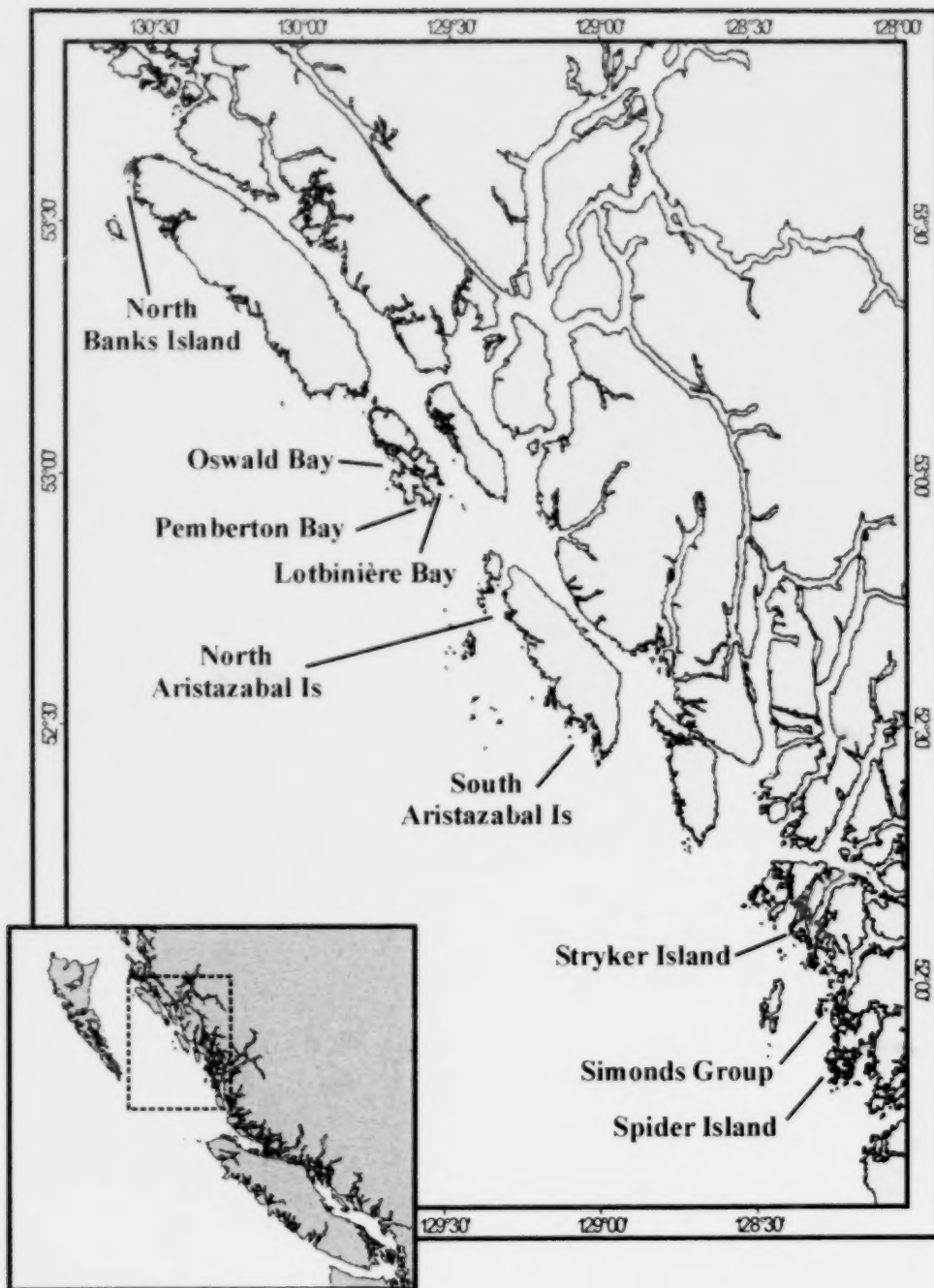


Figure 1. Map of the nine general surveys surveyed on the central coast of BC.

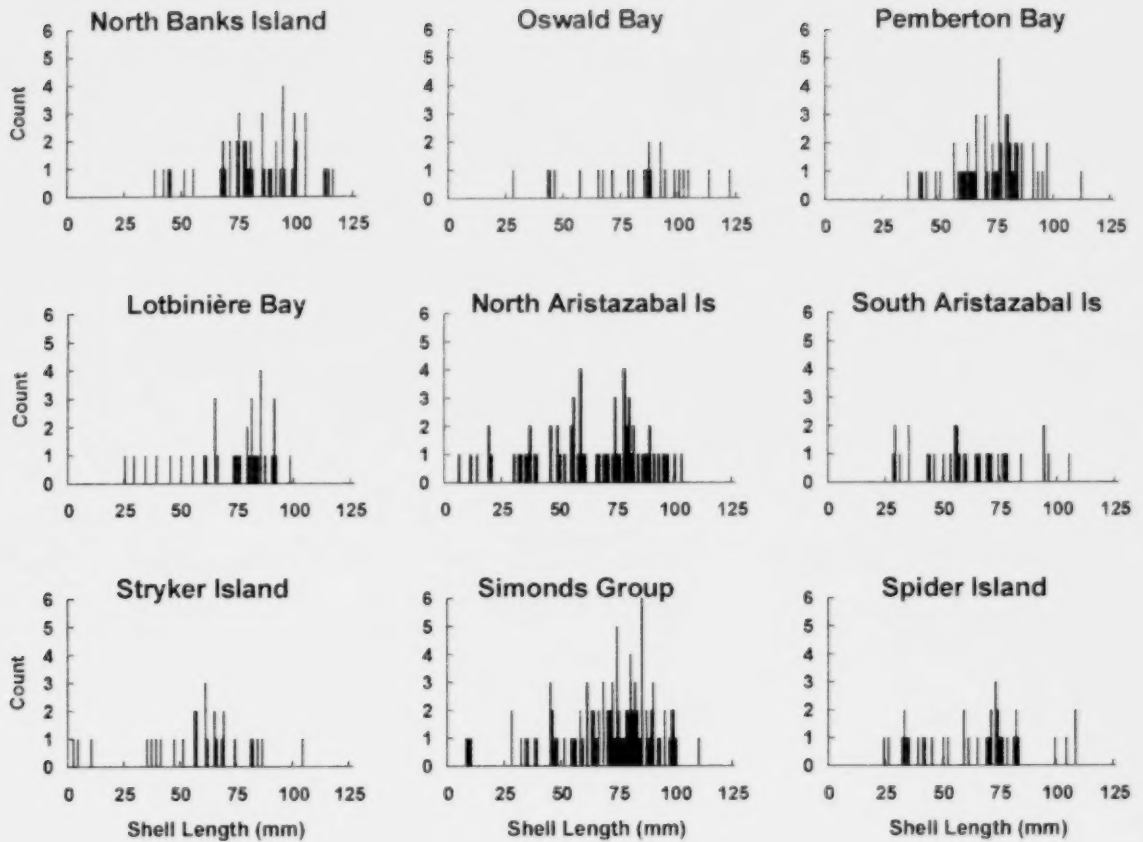


Figure 2. Size frequency of exposed abalone shell lengths measured from each general survey area along the central coast, May 2006.

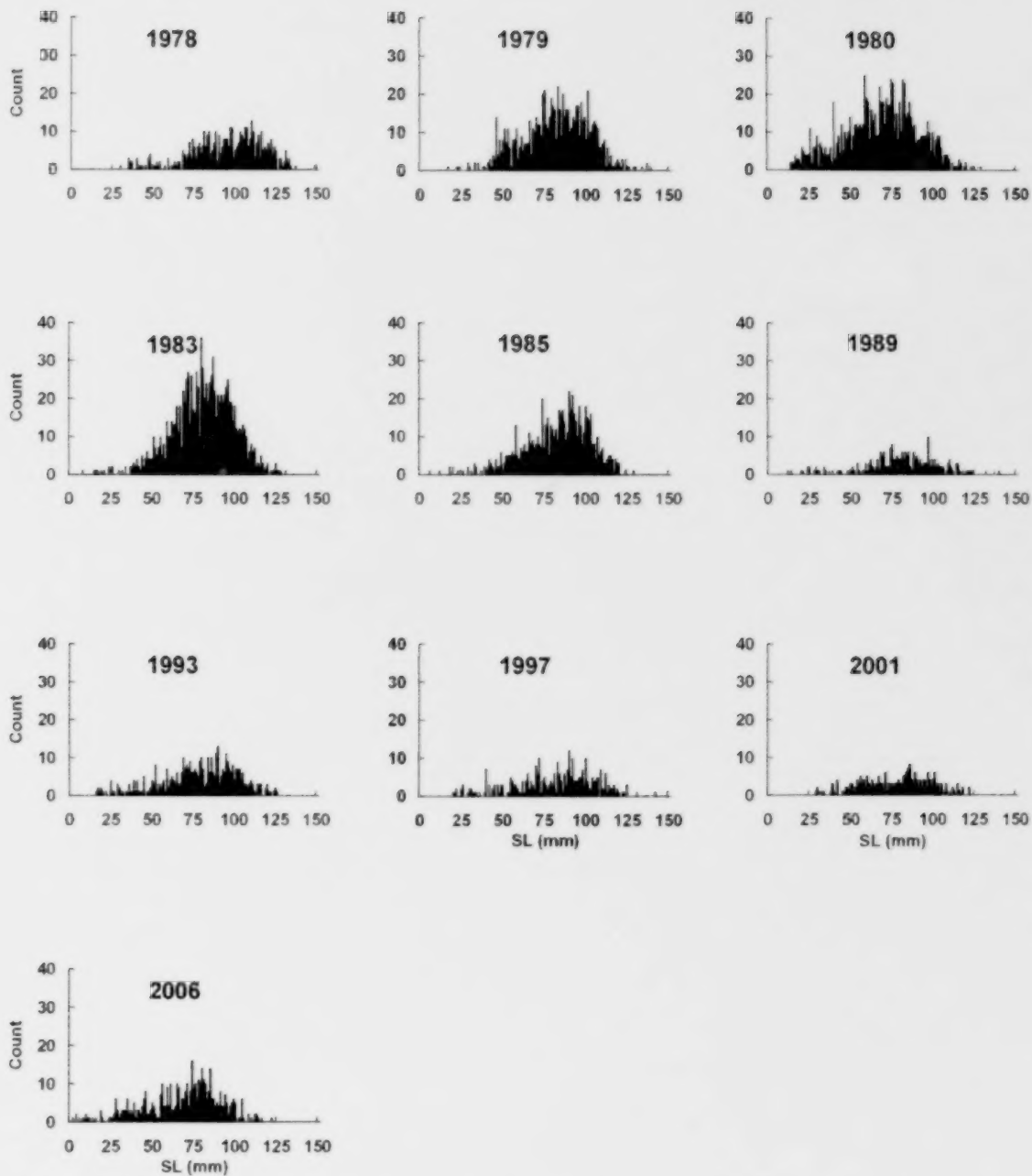


Figure 3. Size frequency of exposed abalone shell lengths measured from all survey sites for all survey years.

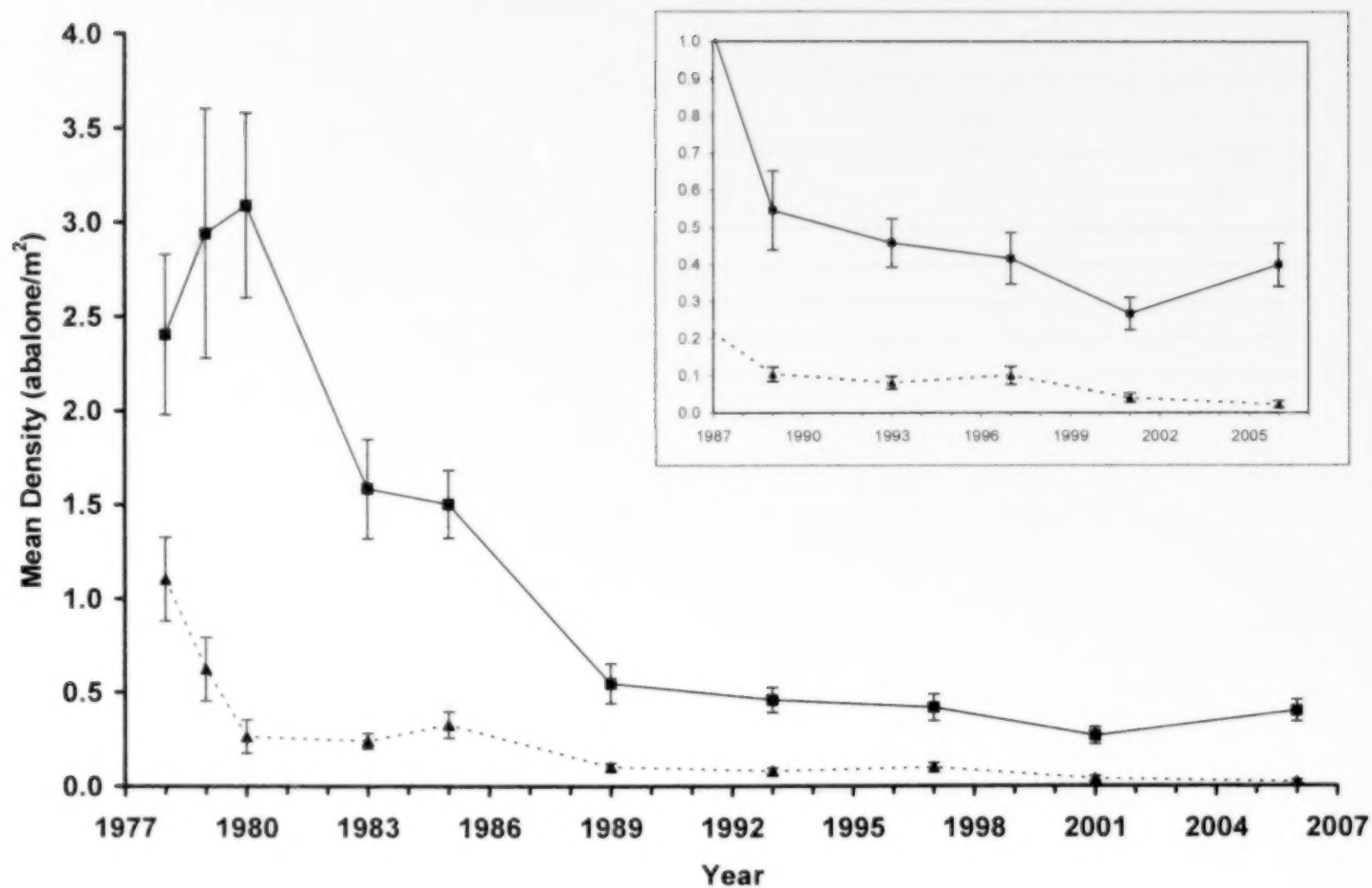


Figure 4. Mean density of 'all sizes' abalone (solid line) and large abalone (dashed line) from all survey years. All sites surveyed are included. Error bars represent SE. Inset graph displays greater resolution of densities for survey years after 1987.

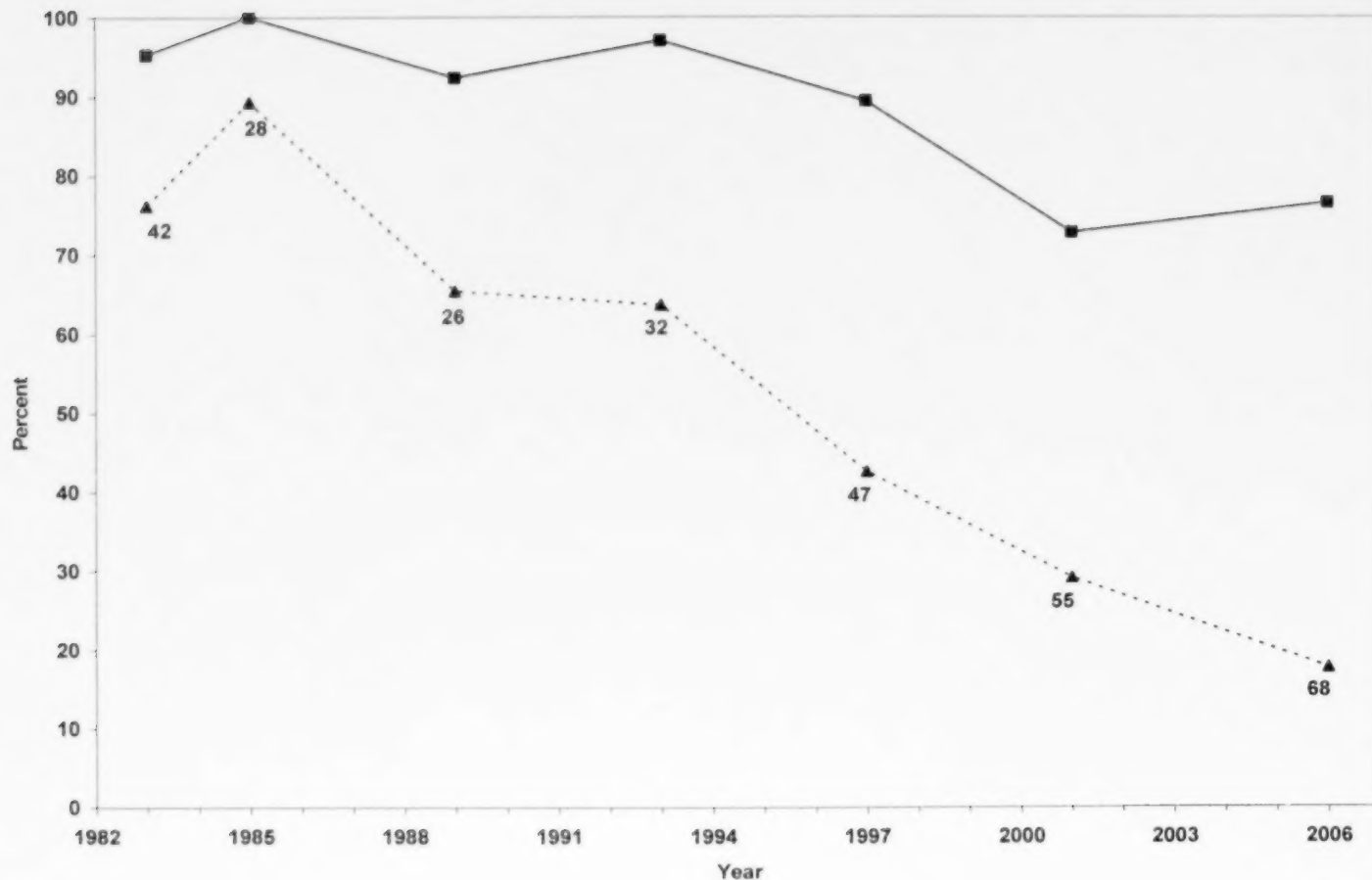


Figure 5. Percent of 'index sites' with exposed abalone of any size (solid line) or exposed large abalone ($\geq 100\text{mm SL}$) (dashed line) from surveys on the central coast, 1983-2006. The years 1978, 1979, and 1980 have been excluded due to small number of 'index sites' in those years. Numbers below the dashed line are sample sizes for each survey year.

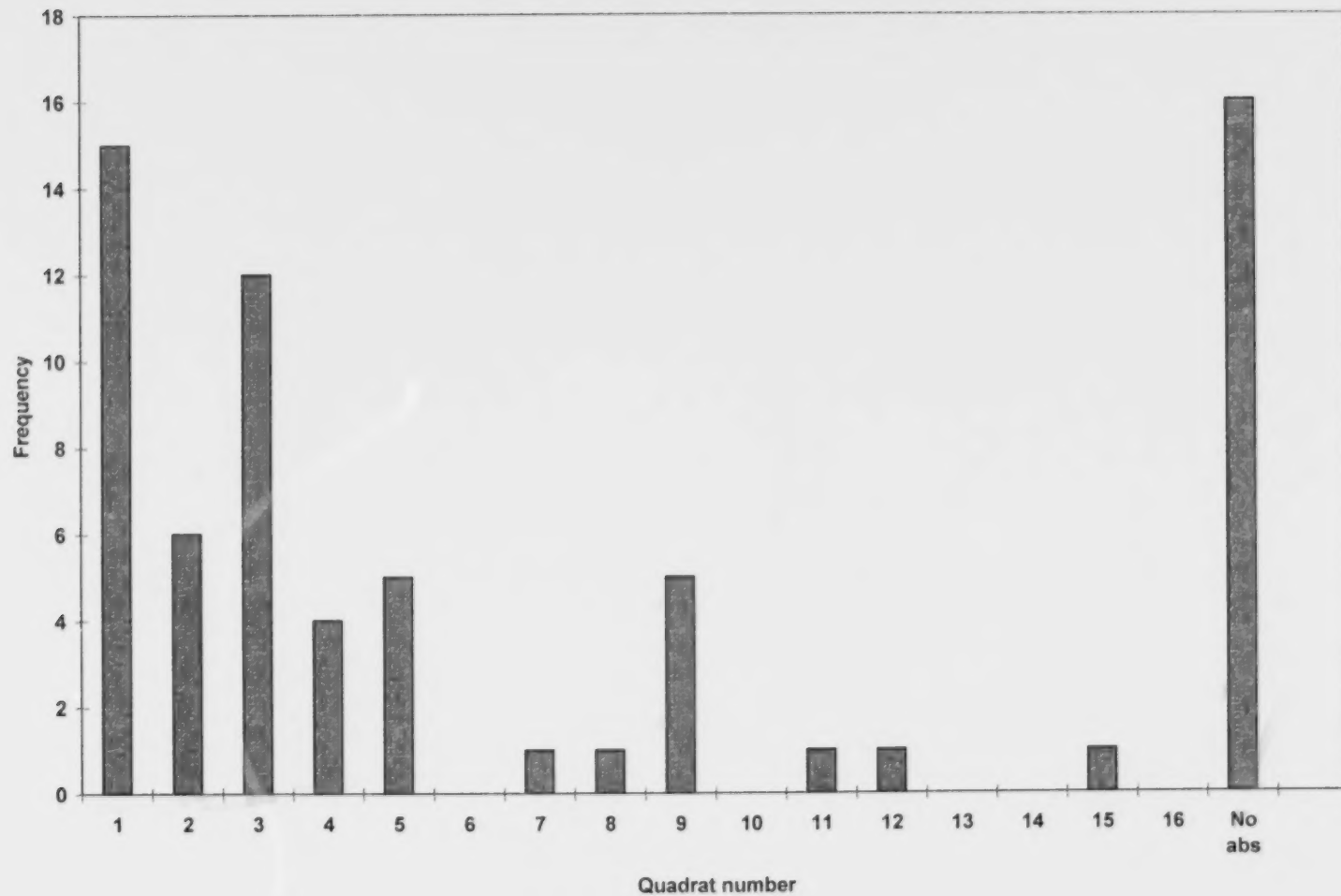


Figure 6. Frequency of the first abalone found at a site for each quadrat number at a given site, for all sites sampled during the 2006 CC index sites survey. No abs refers to the number of sites where no abalone were measured.

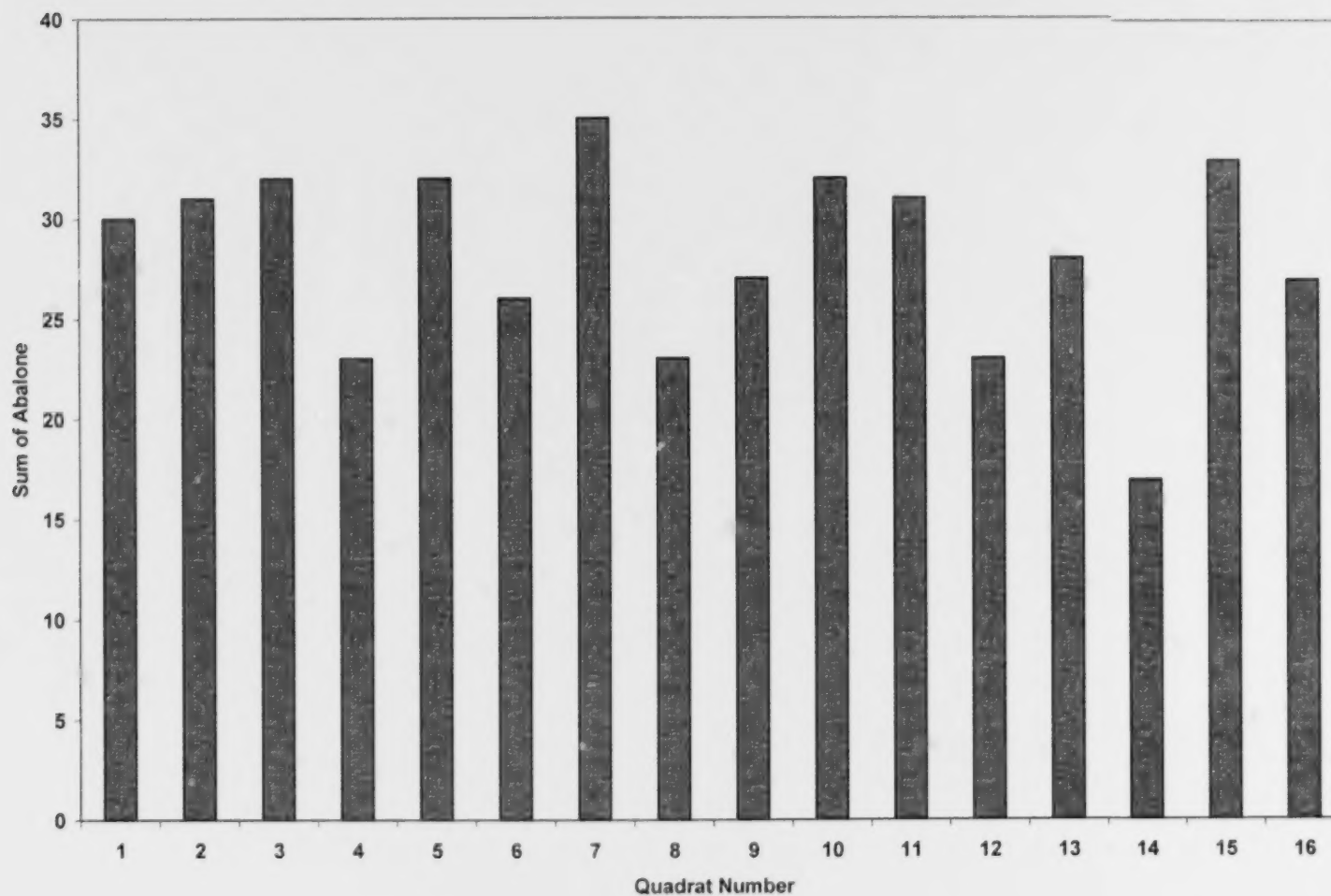


Figure 7. Sum of abalone found in each quadrat number for all sites sampled in the 2006 CC index sites survey.

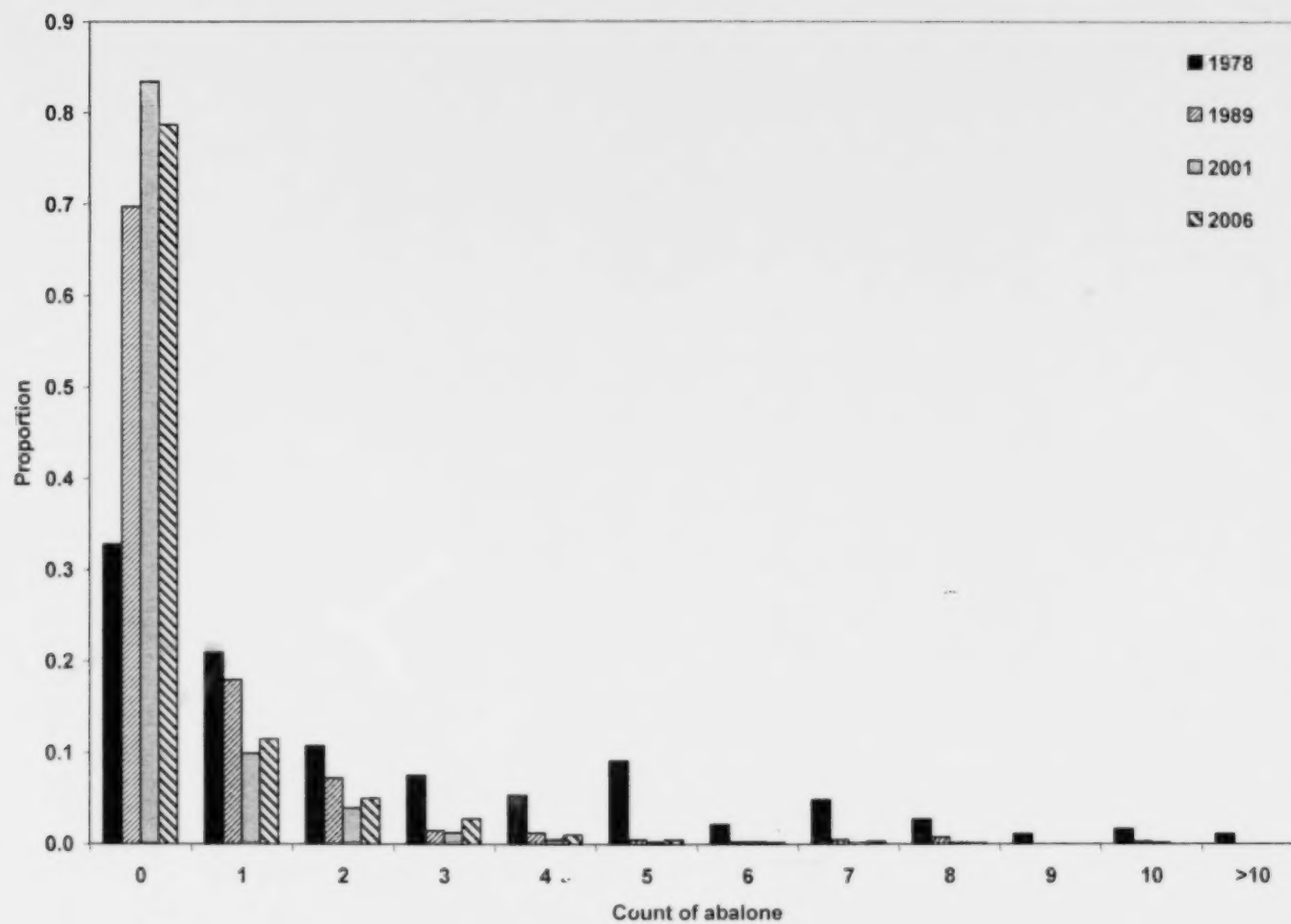


Figure 8. Proportion of quadrats surveyed on the central coast with different abalone counts (all sizes) from all samples in 1978, 1989 (last survey year when fisheries were open), 2001 and 2006.

Appendix 1. Dive summary for the central coast survey, May 2006. Density: number/m²

Site	Date	Dive Time			Depth (m)		Number of quadrats	Abalone		Urchins	
		Start	Finish	Minutes	Min	Max		Count	Density	Count	Density
North Banks Island											
44	May-04	13:32	13:59	27	-1	1	16	0	0.00	4	0.25
45	May-04	14:42	15:26	44	0	2	16	1	0.06	178	11.13
46	May-04	08:52	09:36	44	-1	1	16	33	2.06	106	6.63
47	May-04	10:10	10:39	29	0	2	16	18	1.13	179	11.19
48	May-04	13:09	14:20	71	-2	1	16	0	0.00	392	24.50
49	May-04	12:49	13:13	24	-1	1	16	0	0.00	187	11.69
50	May-04	08:30	09:05	35	0	3	16	0	0.00	47	2.94
51	May-04	09:30	10:10	40	-1	3	16	0	0.00	0	0.00
Oswald Bay											
38	May-14	14:18	14:47	29	-1	4	16	3	0.19	13	0.81
39	May-14	14:15	14:47	32	-1	4	16	1	0.06	159	9.94
40	May-14	13:56	14:55	59	-1	0	16	0	0.00	101	6.31
41	May-14	09:06	09:58	52	1	4	16	4	0.25	372	23.25
42	May-14	10:25	11:15	50	-1	3	16	2	0.13	401	25.06
43	May-06	09:05	10:04	59	-2	0	16	14	0.88	67	4.19
Pemberton Bay											
33	May-05	14:18	14:52	34	1	4	16	21	1.31	87	5.44
34	May-14	11:11	11:47	36	-1	2	16	6	0.38	201	12.56
35	May-14	10:13	10:46	33	-1	2	16	13	0.81	226	14.13
36	May-14	09:05	09:50	45	1	3	16	17	1.06	28	1.75
Lotbinière Bay											
21	May-05	09:34	10:02	28	0	2	16	0	0.00	132	8.25
22	May-05	10:42	11:13	31	-2	0	16	0	0.00	25	1.56
23	May-05	10:06	11:11	65	0	2	16	12	0.75	31	1.94
24	May-05	13:10	14:05	55	-1	1	16	1	0.06	141	8.81
25	May-05	08:55	09:42	47	1	3	16	6	0.38	179	11.19
27	May-05	13:14	13:38	24	1	1	16	3	0.19	63	3.94
29	May-05	08:40	09:12	32	-2	0	16	9	0.56	42	2.63
30	May-05	14:30	15:36	66	-1	2	16	6	0.38	9	0.56
North Aristazabal Is											
13	May-13	14:40	15:15	35	-1	3	16	8	0.50	121	7.56
14	May-13	13:50	14:30	40	-1	1	16	7	0.44	122	7.63
15	May-13	10:32	11:03	31	1	4	16	2	0.13	52	3.25
15A	May-13	11:18	11:57	39	-1	0	16	19	1.19	169	10.56
16	May-13	13:52	14:21	29	0	2	16	3	0.19	89	5.56
16A	May-13	11:05	11:31	26	-1	1	16	0	0.00	43	2.69
17	May-13	09:21	09:55	34	1	4	16	4	0.25	47	2.94
18	May-13	08:35	09:06	31	4	6	16	1	0.06	123	7.69
19	May-13	08:48	09:16	28	1	2	16	12	0.75	57	3.56
20	May-13	09:28	10:24	56	-1	1	16	13	0.81	403	25.19

Appendix 1. Continued. Two depths (denoted with X) were not calculated due to equipment malfunction.

Site	Date	Dive Time			Depth (m)		Number of quadrats	Abalone		Urchins	
		Start	Finish	Minutes	Min	Max		Count	Density	Count	Density
South Aristazabal Is											
03	May-08	13:10	13:55	45	-2	0	16	9	0.56	204	12.75
04	May-08	13:10	13:55	45	-1	1	16	5	0.31	34	2.13
05	May-08	09:45	10:30	45	-2	0	16	0	0.00	101	6.31
08	May-08	14:29	15:11	42	-1	2	16	10	0.63	60	3.75
09	May-08	12:11	12:44	33	-1	0	16	1	0.06	212	13.25
10	May-03	12:15	13:02	47	x	x	15	2	0.13	165	11.00
10A	May-03	12:13	13:12	59	-1	1	16	1	0.06	194	12.13
11	May-03	14:01	14:40	39	0	4	16	3	0.19	123	7.69
12	May-03	14:00	14:24	24	-1	1	16	2	0.13	37	2.31
Stryker Island											
ST121	May-18	08:45	09:15	30	2	4	16	3	0.19	2	0.13
ST190	May-18	10:45	11:15	30	2	8	16	0	0.00	0	0.00
ST220	May-18	11:08	11:35	27	3	6	16	0	0.00	7	0.44
ST304	May-18	13:13	14:05	52	1	5	16	11	0.69	13	0.81
ST359	May-18	13:10	13:40	30	0	9	16	2	0.13	4	0.25
ST411	May-18	08:36	09:17	41	2	7	16	0	0.00	0	0.00
ST444	May-18	09:53	10:43	50	3	7	15	13	0.87	0	0.00
ST483	May-18	09:51	10:22	31	5	10	16	0	0.00	1	0.06
Simonds Group											
SI02	May-16	14:00	14:47	47	-2	0	16	14	0.88	107	6.69
SI03	May-16	14:03	15:01	58	-3	0	16	22	1.38	13	0.81
SI05	May-16	11:16	11:48	32	2	5	16	5	0.31	12	0.75
SI09	May-16	08:53	09:40	47	1	6	16	36	2.25	5	0.31
SI16	May-16	10:13	10:50	37	3	5	16	0	0.00	0	0.00
SI20	May-16	10:35	11:00	25	2	7	16	7	0.44	93	5.81
SI21	May-16	11:20	11:52	32	0	2	16	3	0.19	69	4.31
SI30	May-16	08:55	09:46	51	1	6	16	8	0.50	87	5.44
Spider Island											
SP05	May-17	11:29	12:06	37	-1	3	16	0	0.00	8	0.50
SP08	May-17	13:40	14:12	32	0	4	16	5	0.31	2	0.13
SP13	May-17	09:15	09:52	37	1	4	16	7	0.44	141	8.81
SP17	May-17	11:15	11:40	25	2	8	16	10	0.63	116	7.25
SP32	May-17	10:10	10:37	27	1	3	16	1	0.06	0	0.00
SP33	May-17	13:50	14:42	52	-1	1	16	13	0.81	62	3.88
SP34	May-17	09:29	09:52	23	2	3	16	1	0.06	100	6.25

Appendix 2. Site descriptions of the 68 index sites sampled along the central coast of BC, May, 2006. The most common substrates are listed (1 = first, 2 = second, 3 = third) where substrate code 1 = smooth bedrock, 2 = bedrock with crevices, 3 = boulders, 4 = cobble, 5 = gravel, 7 = sand, and 8 = shell. Algae are listed by growth characteristics for the most common species (Sp 1) and second most common (Sp 2) with percentage cover (%) for each, where AA = *Alaria nana*, AC = articulated corallines, AF = *Agarum fimbriatum*, AG = *Agarum sp.*, AM = *Alaria marginata*, BH = brown filamentous, CO = *Costaria costata*, CY = *Cymathere triplicata*, DL = *Desmarestia ligulata*, DV = *Desmarestia viridis*, DY = *Dyctyota*, EG = *Egregia menziesii*, GB = green branched, GH = green filamentous, GI = *Gigartina sp.*, IR = *Iridaea sp.* (*Maziella sp.*), LB = *Laminaria*, LT = *Laminaria setchellii*, MA = *Macrocystis integrifolia*, NT = *Nereocystis luetkeana*, PH = *Phyllospadix sp.*, PL = *Pleurophycus gardneri*, PT = *Pterygophora californica*, RB = red branched, RF = red foliose, RH = red filamentous, SY = *Scytosiphon sp.*, UL = *Ulva sp.*, ZO = *Zostera sp.*

Site	Substrate			Slope %	Canopy				Understory				Turf				Encrusting %
	1	2	3		Sp	%	Sp	%	Sp	%	Sp	%	Sp	%	Sp	%	
North Banks Island																	
44	4	2	3	10	NT	5		0	CY	70	LB	10		0		0	40
45	3	4		13	NT	30		0	AM	20	CO	5	RB	20	GB	5	90
46	3	2		10	NT	5		0	PH	20	LT	10	AC	30		0	90
47	3	2		17	NT	5		0	PH	10	LT	5	AC	10	UL	5	90
48	2	3	4	13	NT	40		0	AM	30	DL	20	AC	30	RH	5	20
49	3	2		13	NT	1		0	DL	5		0	AC	5	UL	5	90
50	3	7		13		0		0	DV	50	AF	30	AC	20		0	95
51	3	7		21	MA	80		0	AF	90	LS	70	RF	60	AC	50	60
Oswald Bay																	
38	1	8	3	27	MA	70	NT	10	CY	50	AF	20	AC	10	RB	5	70
39	1	3	8	30	NT	5		0	AM	10		0	AC	5	UL	5	100
40	3	4	5	10	MA	15		0	LT	50	AM	20	AC	50		0	70
41	1	2		27	NT	10		0	LT	30	PL	10	AC	20		0	90
42	2	3		21	NT	20		0	PH	20	PY	10	AC	30	RH	5	95
43	3	2		19	NT	20		0	LB	60	HE	20	HE	20	UL	5	100
Pemberton Bay																	
33	2	1		15	NT	5		0	DL	10	CO	1	AC	5	BH	10	80
34	2	3	7	17		0		0		0		0		0		0	70
35	2	3	8	15		0		0	CO	1	AA	1	BH	5	AC	5	80
36	3	4	7	11	NT	2		0	LS	80		0	AC	2		0	70

Appendix 2. Continued.

Site	Substrate			Slope %	Canopy				Understory				Turf				Encrusting %
	1	2	3		Sp	%	Sp	%	Sp	%	Sp	%	Sp	%	Sp	%	
Lotbinière Bay																	
21	3	4	2	15	NT	10		0	DV	20	NT	5	UL	10		0	60
22	3	4	2	8	MA	40		0	LS	30	LT	30	AC	10		0	60
23	2	3		11	NT	5		0	LS	60	CY	40	AC	10	NT	10	100
24	3			8	NT	10		0	LT	20	AM	10	AC	20		0	100
25	3	4		4	NT	5		0	LT	40	PL	30	RF	5	AC	5	90
27	3	4		6	MA	5		0	DV	5		0	UL	15	RF	2	60
29	2			13	NT	1		0	LT	20	DL	5	AC	80		0	40
30	3	2		15	NT	5		0	LT	70	CY	20	CY	20	AC	20	70
North Aristazabal Is																	
13	1	2	8	29	MA	20		0	AM	10	CO	5	AC	10		0	80
14	3	8	4	8		0		0	LB	20	DV	10	AC	40	UL	20	70
15	3	4	2	15		0		0	GF	5	CP	5	AC	15	BH	5	100
15A	3	4		6		0		0	GF	10		0	UL	10	AC	5	95
16	2	3		11	MA	40		0		0		0	AC	70	CP	20	95
16A	2			15	NT	2		0	AM	5	HE	5	UL	20		0	50
17	2	7		21	NT	20		0	DV	40	CO	20	BH	90	AC	10	95
18	2	3	4	15		0		0		0		0	AC	10		0	30
19	2	3	4	8		0		0		0		0	AC	5		0	90
20	3	4	8	13	MA	10	NT	5	DL	10	LB	10	AC	10	UL	5	80
South Aristazabal Is																	
03	3	4		10	NT	10		0	AM	20	CY	10	RB	10	UL	5	80
04	3	2	7	11		0		0	PH	10	DL	2	AC	5	DB	10	90
05	1	2		13	NT	10		0	AM	20	CO	5	AS	10	UL	5	90
08	3	2	4	17	EG	10		0	AM	20	CO	5	DB	10	AC	10	100
09	3	8	4	6	MA	80		0		0		0	AC	20		0	60
10	2			35	NT	5		0	CO	10	AL	10	RH	2	AC	2	100
10A	2	3		10	NT	5		0	AM	10	CY	2	AC	5	BH	5	90
11	2			23	NT	2		0	DL	5	CY	5	AC	2	BH	2	100
12	2			10	NT	5		0	DL	30	CO	20	AC	5		0	90

Appendix 2. Continued.

Site	Substrate			Slope %	Canopy			
	1	2	3		Sp	%	Sp	%
Stryker Island								
ST121	1	2	8	17	MA	100		0
ST190	1	2	8	36	NT	10	MA	5
ST220	3			21	MA	2	NT	1
ST304	1	2	3	27	NT	50		0
ST359	2			51	MA	50		0
ST411	2	3		30	NT	20		0
ST444	2			33	NT	2		0
ST483	1	2	8	29	NT	5		0
Simonds Group								
SI02	3	2		15	NT	60		0
SI03	2	1	3	29	NT	10		0
SI05	1	2	8	23	MA	10	NT	5
SI09	2			32	NT	50		0
SI16	3	4	8	13	NT	20	MA	2
SI20	2	3		36		0		0
SI21	3			13	NT	10	EG	2
SI30	2	1	3	29	NT	90		0
Spider Island								
SP05	2	8		25	MA	100		0
SP08	1	2	8	25	MA	100		0
SP13	1	2	3	17	NT	5		0
SP17	1	2	3	32	NT	5		0
SP32	1	2	3	11	NT	40		0
SP33	3			10	NT	10		0
SP34	3	4	7	10	NT	10		0

	Understory				Turf				Encrusting %
	Sp	%	Sp	%	Sp	%	Sp	%	
0	LT	20	DL	5	RF	20	AC	10	80
5	LT	20	DL	20	BF	10	RB	5	70
1	LB	80	LS	10	RB	5	AC	2	95
0	LT	30	DL	10	BF	20	AC	10	90
0	AG	10		0	AC	10		0	70
0	LT	90	LS	5	RH	15		0	100
0	LT	80	PL	5	RH	15	AC	15	100
0	LT	50	PT	5	RF	30	RB	20	50
0	AM	30	CO	30	AC	5		0	100
0	AM	80	LB	80	CA	25	FU	5	80
5	LB	80	MA	60	AC	60		0	90
0	LT	80	DL	80	DL	20	AC	10	100
0	CY	100	AF	80	AC	40	BF	20	40
0	LS	10	NT	10	BH	30	AC	5	95
0	PT	100	LS	40	RF	20	AC	20	95
0	DL	50	LT	20	RB	30		0	90
0		0		0	AC	40		0	95
0	LA	5		0		0		0	100
0	CO	10	DM	5	AC	5		0	100
0	CO	5	DL	5	AC	5	BH	5	100
0	LT	100	DL	10	RB	50	RF	10	100
0	LA	50	AL	50	AC	5		0	90
0	UL	40	CO	5	BH	40	AC	1	95

Appendix 3. Number of quadrat sampled, count of abalone, mean SL of abalone measured and density estimates of exposed abalone by size category for each index sites surveyed along the central coast in May 2006.

Site	Number of quadrats	Mean size	Abalone counted	Density Estimate (abalone/m ²)			
				Total	Immature	Mature	Large
North Banks Island							
44	16		0	0.00	0.00	0.00	0.00
45	16	71.0	1	0.06	0.00	0.06	0.00
46	16	88.5	33	2.06	0.25	1.81	0.56
47	16	73.6	18	1.13	0.38	0.75	0.00
48	16		0	0.00	0.00	0.00	0.00
49	16		0	0.00	0.00	0.00	0.00
50	16		0	0.00	0.00	0.00	0.00
51	16		0	0.00	0.00	0.00	0.00
Oswald Bay							
38	16	94.3	3	0.19	0.00	0.19	0.06
39	16	86.0	1	0.06	0.00	0.06	0.00
40	16		0	0.00	0.00	0.00	0.00
41	16	69.0	4	0.25	0.19	0.06	0.00
42	16	37.0	2	0.13	0.13	0.00	0.00
43	16	86.4	14	0.88	0.13	0.75	0.25
Pemberton Bay							
33	16	66.7	21	1.31	0.69	0.63	0.00
34	16	74.0	6	0.38	0.06	0.31	0.00
35	16	73.3	13	0.81	0.38	0.44	0.06
36	16	78.8	17	1.06	0.13	0.94	0.00
Lotbinière Bay							
21	16		0	0.00	0.00	0.00	0.00
22	16		0	0.00	0.00	0.00	0.00
23	16	78.2	12	0.75	0.19	0.56	0.00
24	16	85.0	1	0.06	0.00	0.06	0.00
25	16	56.7	6	0.38	0.19	0.19	0.00
27	16	83.0	3	0.19	0.06	0.13	0.00
29	16	70.9	9	0.56	0.19	0.38	0.00
30	16	69.5	6	0.38	0.19	0.19	0.00
North Aristazabal Is							
13	16	68.3	8	0.50	0.19	0.31	0.00
14	16	51.9	7	0.44	0.38	0.13	0.00
15	16	45.0	2	0.13	0.13	0.00	0.00
15A	16	64.9	19	1.19	0.63	0.56	0.00
16	16	18.0	3	0.19	0.19	0.00	0.00
16A	16		0	0.00	0.00	0.00	0.00
17	16	55.5	4	0.25	0.13	0.13	0.00
18	16	14.0	1	0.06	0.06	0.00	0.00
19	16	80.1	12	0.75	0.19	0.56	0.06
20	16	65.1	13	0.81	0.44	0.38	0.06

Appendix 3. Continued.

Site	Number of quadrats	Mean size	Abalone counted	Density Estimate (abalone/m ²)			
				Total	Immature	Mature	Large
South Aristazabal Is							
03	16	59.7	9	0.56	0.38	0.19	0.06
04	16	60.0	5	0.31	0.19	0.13	0.00
05	16		0	0.00	0.00	0.00	0.00
08	16	63.2	10	0.63	0.31	0.31	0.00
09	16	94.0	1	0.06	0.00	0.06	0.00
10	15	49.5	2	0.13	0.13	0.00	0.00
10A	16	56.0	1	0.06	0.06	0.00	0.00
11	16	55.0	3	0.19	0.19	0.00	0.00
12	16	60.5	2	0.13	0.13	0.00	0.00
Stryker Island							
ST121	16	74.0	3	0.19	0.06	0.31	0.00
ST190	16		0	0.00	0.00	0.00	0.00
ST220	16		0	0.00	0.00	0.00	0.00
ST304	16	34.2	11	0.69	1.00	0.00	0.00
ST359	16	41.5	2	0.13	0.44	0.06	0.06
ST411	16		0	0.00	0.00	0.00	0.00
ST444	15	63.2	13	0.87	0.73	0.13	0.00
ST483	16		0	0.00	0.00	0.00	0.00
Simonds Group							
SI02	16	81.2	14	0.88	0.13	0.75	0.00
SI03	16	77.7	22	1.38	0.31	1.06	0.06
SI05	16	78.8	5	0.31	0.06	0.25	0.00
SI09	16	62.7	36	2.25	1.38	0.88	0.06
SI16	16		0	0.00	0.00	0.00	0.00
SI20	16	60.1	7	0.44	0.25	0.19	0.00
SI21	16	61.7	3	0.19	0.06	0.13	0.00
SI30	16	67.5	8	0.50	0.13	0.38	0.00
Spider Island							
SP05	16		0	0.00	0.00	0.00	0.00
SP08	16	77.8	5	0.31	0.13	0.19	0.06
SP13	16	67.9	7	0.44	0.13	0.31	0.00
SP17	16	36.9	10	0.63	0.63	0.00	0.00
SP32	16	32.0	1	0.06	0.06	0.00	0.00
SP33	16	79.8	13	0.81	0.13	0.69	0.13
SP34	16	52.0	1	0.06	0.06	0.00	0.00

Appendix 4. Total exposed abalone density and number of quadrats by index site on the central coast for all survey years. Blanks indicate sites were not surveyed that year.

Site	Total Density (abalone/m ²)										Number of quadrats sampled per site									
	1978	1979	1980	1983	1985	1989	1993	1997	2001	2006	1978	1979	1980	1983	1985	1989	1993	1997	2001	2006
North Banks Island																				
44		2.98					0.04	0.19	0.44	0.00		16					24	16	16	16
45		1.65					0.25	0.13	0.06	0.06		16					24	16	16	16
46		1.13					1.03	0.25	0.63	2.06		16					32	32	16	16
47		0.29					0.21	0.44	0.63	1.13		16					24	16	16	16
48	2.81									0.00	16									16
49	2.25									0.00	16									16
50	1.50									0.00	16									16
51	0.88									0.00	16									16
Oswald Bay																				
38				2.26			0.59	0.56	0.00	0.19			16				32	16	8	16
39				4.13			0.38	0.44	0.19	0.06			16				32	16	16	16
40				0.59			0.47	0.00	0.06	0.00			16				32	8	16	16
41				0.90						0.25			16							16
42				0.36						0.13			16							16
43				0.50						0.88			16							16
Pemberton Bay																				
33				1.68	0.84	0.50	1.25	0.31	0.00	1.31			16	15	16		32	16	16	16
34				2.28	0.98	0.00	0.00	0.00	0.13	0.38			16	17	8		8	16	16	16
35				3.09	1.35	0.06	0.41	0.44	0.31	0.81			16	16	16		32	16	16	16
36		9.51		1.51	3.32	1.44	0.17	0.81	0.44	1.06		16	16	16	16		24	16	16	16

Appendix 4. Continued.

Site	Total Density (abalone/m ²)										Number of quadrats sampled per site									
	1978	1979	1980	1983	1985	1989	1993	1997	2001	2006	1978	1979	1980	1983	1985	1989	1993	1997	2001	2006
Lotbinière Bay																				
21		1.34		1.35	1.30	0.13	0.25	0.00	0.38	0.00		16		16	16	16	32	16	16	16
22		0.79		0.62	0.59	0.38	0.09	0.00	0.44	0.00		16		16	16	16	32	16	16	16
23		4.19		2.38	2.42	1.06	0.63	1.06	0.69	0.75		16		16	16	16	32	16	16	16
24		1.55		0.66	0.84	0.19	0.19	0.00	0.00	0.06		16		16	16	16	16	8	8	16
25				1.73	1.09	0.63	0.31	0.06	0.06	0.38				16	16	16	32	16	16	16
27			1.20	0.33	0.62	0.19	0.53	0.19	0.00	0.19			16	16	16	16	32	16	16	16
29				2.02	1.93	0.13	0.66	0.19	1.13	0.56				16	16	16	32	16	16	16
30				4.51	2.85	1.00	1.81	0.50	0.63	0.38				16	16	16	32	16	16	16
North Aristazabal Is																				
13				0.55	2.02	0.19	0.19	0.19	0.13	0.50				16	16	16	32	16	16	16
14				1.98						0.44				16						16
15				1.03	1.08	2.25	0.50	0.19	0.31	0.13				16	16	16	16	16	16	16
15A							0.44	0.13	0.25	1.19							16	16	16	16
16				0.34	1.22	0.25	0.88	0.63	0.94	0.19				16	16	16	32	16	16	16
16A										0.00										
17				1.60	2.16	0.94	0.44	0.19	0.44	0.25				16	16	16	32	16	16	16
18				0.00		1.13				0.06				8						16
19				1.03	1.50	0.44	0.41	0.06	0.00	0.75				16	16	16	32	16	16	16
20				0.37	0.80	0.38	0.44	0.75	0.13	0.81				16	16	16	32	16	16	16

Appendix 4. Continued.

Site	Total Density (abalone/m ²)										Number of quadrats sampled per site									
	1978	1979	1980	1983	1985	1989	1993	1997	2001	2006	1978	1979	1980	1983	1985	1989	1993	1997	2001	2006
South Aristazabal Is																				
02				0.23					0.06					16					16	
03				0.68					0.06	0.56				16					16	16
04				0.50	0.23	1.31	0.13		0.06	0.31				16	16	16	24		16	16
05				0.00					0.00	0.00				8					8	16
06				0.92	0.23	0.06	0.33	0.13	0.13					16	16	16	24	16	16	
07				2.09					0.13					8					16	
08				2.27	2.71	0.50	0.28	0.00	0.06	0.63				16	16	16	32	8	16	16
09				0.86	1.01	0.19	0.04	0.06	0.19	0.06				16	16	16	24	16	16	16
10				0.97	4.06	0.50	0.28	0.13	0.00	0.13				16	16	16	32	16	8	15
10A			5.09							0.06			16							16
11				0.72	1.66	0.38	0.63	0.25	0.13	0.19				16	16	16	16	16	16	16
12				0.68	1.00	0.00	0.88	0.25	0.13	0.13				16	16	8	16	16	16	16
Stryker Island																				
ST121								2.56	0.94	0.19									16	16
ST190								0.63	0.00	0.00									16	8
ST220								0.69	0.00	0.00									16	8
ST304								0.31	0.63	0.69									16	16
ST359								0.19	0.00	0.13									16	16
ST411								0.19	0.25	0.00									16	8
ST444								0.50	0.00	0.87									16	8
ST483								0.44	0.00	0.00									16	8
Simonds Group																				
SI02										0.88										16
SI03										1.38										16
SI05								1.50	1.44	0.31									16	16
SI09								0.50	0.50	2.25									16	16
SI16								0.75	0.06	0.00									16	16
SI20								0.69	0.13	0.44									16	16
SI21								0.38	0.00	0.19									16	8
SI30									0.00	0.50										8

Appendix 4. Continued.

Site	Total Density (abalone/m ²)										Number of quadrats sampled per site									
	1978	1979	1980	1983	1985	1989	1993	1997	2001	2006	1978	1979	1980	1983	1985	1989	1993	1997	2001	2006
Spider Island																				
SP05								0.00	0.00									0	16	
SP08								0.13	0.31									16	16	
SP13								0.19	0.69	0.44								16	16	16
SP17								1.56	0.63	0.63								16	16	16
SP32			1.95							0.06				16						16
SP33			6.72							0.81				16						16
SP34			4.14							0.06				16						16

Appendix 5. Large and mature exposed abalone densities by index site on the central coast for all survey years. Blanks indicate sites not surveyed.

Site	Large Density (abalone/m ²)										Mature Density (abalone/m ²)									
	1978	1979	1980	1983	1985	1989	1993	1997	2001	2006	1978	1979	1980	1983	1985	1989	1993	1997	2001	2006
North Banks Island																				
44		0.57						0.06	0.19	0.00			2.18					0.19	0.31	0.00
45		0.09					0.21	0.13	0.06	0.00			1.33					0.13	0.06	0.06
46		0.25					0.26	0.00	0.19	0.56			0.87				0.25	0.25	0.44	1.81
47		0.06					0.00	0.13	0.06	0.00			0.19				0.87	0.31	0.44	0.75
48	1.32									0.00	2.64						0.16			0.00
49	0.93									0.00	1.92									0.00
50	0.88									0.00	1.44									0.00
51	0.51									0.00	0.88									0.00
Oswald Bay																				
38				0.32			0.22	0.25	0.00	0.06			2.10				0.53	0.56	0.00	0.19
39				1.10			0.00	0.06	0.00	0.00			3.66				0.19	0.38	0.00	0.06
40				0.12			0.03	0.00	0.06	0.00			0.43				0.38	0.00	0.06	0.00
41				0.00						0.00			0.74							0.06
42				0.06						0.00			0.31							0.00
43				0.14						0.25			0.50							0.75
Pemberton Bay																				
33				0.19	0.07	0.00	0.03	0.00	0.00	0.00			1.41	0.73	0.38	0.94	0.06	0.00	0.63	
34				0.29	0.17	0.00	0.00	0.00	0.00	0.00			1.90	0.93	0.00	0.00	0.00	0.13	0.31	
35				0.19	0.06	0.00	0.00	0.19	0.00	0.06			2.04	0.31	0.00	0.13	0.44	0.19	0.44	
36		2.46		0.13	0.99	0.13	0.04	0.06	0.00	0.00		9.14	0.97	3.16	1.06	0.08	0.69	0.31	0.94	

Appendix 5. Continued.

Site	Large Density (abalone/m ²)										Mature Density (abalone/m ²)									
	1978	1979	1980	1983	1985	1989	1993	1997	2001	2006	1978	1979	1980	1983	1985	1989	1993	1997	2001	2006
Lotbinière Bay																				
21	0.83			0.42	0.93	0.13	0.22	0.00	0.25	0.00		1.19		0.95	1.30	0.13	0.25	0.00	0.38	0.00
22	0.29			0.31	0.19	0.31	0.06	0.00	0.13	0.00		0.69		0.62	0.43	0.38	0.06	0.00	0.38	0.00
23	0.87			0.25	0.12	0.19	0.03	0.19	0.13	0.00		3.29		1.55	2.11	0.97	0.41	0.88	0.69	0.56
24	0.38			0.00	0.31	0.06	0.13	0.00	0.00	0.00		1.24		0.56	0.68	0.19	0.19	0.00	0.00	0.06
25				0.37	0.29	0.25	0.03	0.00	0.00	0.00				1.67	0.94	0.56	0.25	0.06	0.00	0.19
27			0.27	0.12	0.25	0.19	0.16	0.19	0.00	0.00			0.68	0.12	0.62	0.19	0.41	0.19	0.00	0.13
29				0.29	0.70	0.00	0.00	0.06	0.06	0.00				1.87	1.66	0.13	0.31	0.19	0.56	0.38
30				0.89	1.43	0.30	0.25	0.25	0.13	0.00				3.75	2.85	1.00	1.59	0.50	0.44	0.19
North Aristazabal Is																				
13				0.06	0.26	0.00	0.00	0.13	0.00	0.00				0.50	1.21	0.19	0.06	0.19	0.06	0.31
14				0.12						0.00				1.61						0.13
15				0.25	0.12	0.12	0.00	0.00	0.00	0.00				0.93	0.56	1.72	0.13	0.06	0.13	0.00
15A								0.00	0.00	0.00							0.38	0.00	0.13	0.56
16				0.06	0.13	0.06	0.06	0.00	0.06	0.00				0.19	0.78	0.25	0.53	0.06	0.56	0.00
16A							0.06			0.00										0.00
17				0.00	0.00	0.06	0.03	0.00	0.00	0.00				0.87	1.43	0.63	0.13	0.13	0.19	0.13
18				0.00		0.00				0.00				0.00		0.50				0.00
19				0.53	0.56	0.19	0.15	0.06	0.00	0.06				0.90	1.24	0.31	0.30	0.06	0.00	0.56
20				0.31	0.37	0.19	0.38	0.38	0.00	0.06				0.37	0.74	0.38	0.41	0.75	0.00	0.38

Appendix 5. Continued.

Site	Large Density (abalone/m ²)										Mature Density (abalone/m ²)									
	1978	1979	1980	1983	1985	1989	1993	1997	2001	2006	1978	1979	1980	1983	1985	1989	1993	1997	2001	2006
South Aristazabal Is																				
02				0.00					0.00					0.17					0.00	
03				0.00					0.00	0.06				0.00					0.00	0.19
04				0.25	0.06	0.07	0.00		0.00	0.00				0.50	0.12	0.39	0.00		0.06	0.13
05				0.00					0.00	0.00				0.00					0.00	0.00
06				0.00	0.00	0.00	0.04	0.00	0.00					0.19	0.12	0.00	0.13	0.00	0.06	
07				0.00					0.00					0.00					0.00	
08				0.38	0.25	0.19	0.00	0.00	0.00	0.00				2.17	2.29	0.31	0.00	0.00	0.00	0.31
09				0.00	0.43	0.00	0.00	0.00	0.00	0.00				0.81	0.81	0.06	0.04	0.06	0.13	0.06
10				0.19	1.04	0.14	0.13	0.00	0.00	0.00				0.87	3.91	0.50	0.28	0.00	0.00	0.00
10A			0.63							0.00			4.83							0.00
11				0.07	0.00	0.13	0.00	0.00	0.00	0.00				0.27	0.62	0.38	0.25	0.06	0.06	0.00
12				0.25	0.19	0.00	0.13	0.00	0.00	0.00				0.68	0.74	0.00	0.50	0.25	0.00	0.00
Stryker Island																				
ST121								0.50	0.19	0.00								2.13	0.81	0.31
ST190								0.00	0.00	0.00								0.50	0.00	0.00
ST220								0.31	0.00	0.00								0.69	0.00	0.00
ST304								0.00	0.00	0.00								0.19	0.19	0.00
ST359								0.00	0.00	0.06								0.13	0.00	0.06
ST411								0.00	0.00	0.00								0.00	0.00	0.00
ST444								0.00	0.00	0.00								0.06	0.00	0.13
ST483								0.00	0.00	0.00								0.00	0.00	0.00
Simonds Group																				
SI02										0.00										0.75
SI03										0.06										1.06
SI05								0.75	0.50	0.00								1.25	1.19	0.25
SI09								0.00	0.00	0.06								0.44	0.25	0.88
SI16								0.50	0.06	0.00								0.75	0.06	0.00
SI20								0.31	0.00	0.00								0.56	0.13	0.19
SI21								0.00	0.00	0.00								0.06	0.00	0.13
SI30									0.00	0.00									0.00	0.38

Appendix 5. Continued.

Site	Large Density (abalone/m ²)										Mature Density (abalone/m ²)									
	1978	1979	1980	1983	1985	1989	1993	1997	2001	2006	1978	1979	1980	1983	1985	1989	1993	1997	2001	2006
Spider Island																				
SP05								0.00	0.00									0.00	0.00	
SP08								0.13	0.06									0.13	0.19	
SP13								0.19	0.00	0.00								0.19	0.44	0.31
SP17								0.00	0.00	0.00								0.50	0.23	0.00
SP32			0.19							0.00			1.09							0.00
SP33			0.00							0.13			1.91							0.69
SP34			0.25							0.00			2.10							0.00

Appendix 6. Index sites added in 2006 with their previous site numbers and the original survey year for each site.

Previous site number (Year- Site)	New site number
78-09	48
78-10	49
78-11	50
78-12	51
79-16	16A
80-57	SP 32
80-58	SP 33
80-59	SP 34
83-14	14
83-41	41
83-42	42
83-43	43

Appendix 7. Number of quadrat sampled, abalone count, mean SL and exposed abalone densities across all size categories for additional (non-repeated) surveyed sites during the 1978, 1979, 1983, and 1985 surveys.

Year-Site	Number of quadrats	Total Count	Mean SL (mm)	Density estimates (abalone/m ²)			
				Total	immature	mature	large
78-01	16	78	103.4	4.88	0.19	4.69	3.00
78-02	16	10	89.7	0.63	0.25	0.38	0.38
78-03	12	7	107.0	0.58	0.00	0.58	0.50
78-05	16	43	89.9	2.69	0.24	2.44	0.79
78-06	14	71	89.6	5.07	0.85	4.23	1.77
78-07	16	51	78.5	3.19	0.84	2.35	0.30
78-08	16	37	107.7	2.31	0.00	2.31	1.69
78-13	16	33	93.4	2.06	0.35	1.71	1.18
79-14	16	17	84.3	1.02	0.18	0.84	0.26
79-22	16	79	85.2	4.75	0.77	3.98	1.17
79-23	16	62	73.4	3.62	1.17	2.46	0.15
79-24	16	94	77.4	5.50	1.72	3.78	0.99
79-27	16	49	74.8	2.83	1.10	1.73	0.37
80-03	16	69	58.7	3.80	2.56	1.24	0.06
80-12	16	12	71.3	0.68	0.25	0.43	0.12
80-18	13	82	66.2	5.77	2.57	3.20	0.38
80-22	16	134	65.0	7.57	3.91	3.66	0.18
80-29	16	47	56.6	2.63	1.49	1.14	0.00
80-30	16	28	92.3	1.71	0.11	1.61	0.64
80-52	16	65	91.8	3.98	0.26	3.72	1.65
80-53	14	52	69.7	3.38	1.65	1.73	0.15
80-61	16	26	53.3	1.41	1.07	0.34	0.00
80-62	18	35	63.0	1.75	0.96	0.79	0.11
80-63	16	10	82.5	0.60	0.09	0.51	0.23
80-65	16	24	70.7	1.41	0.42	0.99	0.06
80-66	16	8	65.1	0.46	0.18	0.28	0.00
80-68	12	59	66.0	4.38	2.64	1.74	0.09
83-26	16	169	79.1	9.97	2.67	7.31	0.91
83-28	16	24	95.4	1.47	0.11	1.35	0.61
83-31	16	19	85.8	1.14	0.21	0.93	0.31
83-32	16	62	83.4	3.75	0.51	3.23	0.49
83-37	16	39	80.9	2.36	0.31	2.04	0.19
85-01	16	45	68.5	2.55	1.26	1.29	0.07
85-02	16	12	81.3	0.72	0.14	0.57	0.11
85-18b	16	15	85.7	0.90	0.15	0.76	0.06

